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(54) **METHOD FOR PRODUCING MAGNESIUM BASE ALLOY FORMED ARTICLE**

(57) The present invention provides a producing method of a magnesium-based alloy wrought product capable of producing a plastic processing wrought product made of magnesium-based alloy with excellent productivity.

A drawn material made of magnesium-based alloy obtained by drawing processing is subjected to plastic processing into a wrought product at processing temperature of lower than 250°C.

Since the alloy structure is finely divided by the drawing processing, plastic workability can be enhanced in the plastic processing even if the processing temperature is lower than 250°C.

Examples of the plastic processing are forging processing, swaging processing and bending processing.

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Description

Technical Field

[0001] The present invention relates to a method for producing a wrought product made of magnesium-based alloy by plastic processing. More particularly, the invention relates to a producing method of a magnesium-based alloy wrought product capable of producing the wrought product with more excellent productivity while lowering a processing temperature when the plastic working is carried out.

Background Technique

[0002] The magnesium-based alloy is lighter than aluminum in weight, and has more excellent specific strength and specific rigidity as compared with steel or aluminum and thus, the magnesium-based alloy is widely used for aircraft parts, automobile parts, bodies of various electrical products and the like.

[0003] However, since Mg and its alloy have hexagonal close-packed lattice (hcp) structure, they have poor ductility and their plastic workability is extremely poor. It is widely known that workability of magnesium-based alloy becomes excellent if the temperature is increased at the time of processing. For example, Japanese Patent Applications Laid-open Nos.2000-283134 and 2000-343178 describe technique for processing a screw in a temperature state in which magnesium-based alloy material generates superplasticity phenomenon.

[0004] When magnesium-based alloy material is plastically processed, however, since the temperature at which the superplasticity phenomenon is generated is as high as 250°C or higher, the conventional method has a problem that a wrought product can not be produced by the plastic processing with excellent productivity.

[0005] Conventionally, when severe processing such as plastic processing is to be carried out to obtain a wrought product made of magnesium-based alloy, although conditions differ depending upon processing degree, it is necessary to heat extruded material or rolled material made of magnesium-based alloy which is to be processed to 250°C or higher and to process the material. Therefore, heat equipment for high temperature as high as 250°C or higher is not only required, but a mold used for the plastic processing and a processing material such as a roll are also exposed to high temperature and their lifetimes are shortened, and this increases the processing cost. Thus, it is by no means preferable for industrial production to heat material to 250°C or higher.

[0006] It is a main object of the present invention to provide a producing method of a magnesium-based alloy wrought product capable of producing a plastically processed wrought product made of magnesium-based alloy with excellent productivity.

Disclosure of the Invention

[0007] It is generally considered it difficult to carry out severe processing such as plastic processing for magnesium-based alloy. The present inventors variously researched and found that if a magnesium-based alloy material which is previously subjected to specific drawing processing is used, plastic processing can be carried out even if the processing temperature is less than 250°C, and achieved the present invention.

[0008] That is, the producing method of a magnesium-based alloy wrought product of the present invention is characterized in that a drawn material made of magnesium-based alloy obtained by drawing processing is subjected to plastic processing into a wrought product at a processing temperature of less than 250°C.

[0009] Conventionally, when a magnesium-based alloy material is subjected to plastic processing to obtain a wrought product, extruded material or rolled material is used as material to be processed. However, if the extruded material or rolled material is used, it must be heated to 250°C or higher at the time of plastic processing, and it is strongly desired to lower the processing temperature. The present invention lowers the processing temperature by using not extruded material or rolled material but a drawn material obtained by the drawing processing, i.e., the invention realizes a plastic processing at less than 250°C, especially at 200°C or lower. According to the invention, it is possible to lower the processing temperature at the time of plastic processing to less than 250°C by using a drawn material, the conventional high temperature heating means is unnecessary, lifetime of a processing material such as a mold or roll used for the plastic processing can be increased, and productivity can be enhanced. The present invention will be explained in more detail.

[0010] Examples of the drawn material made of magnesium-based alloy of the invention are a wire (line-like body), a rod-like body, a pipe and the like. A cross section of the drawn material may be of circular, rectangular, non-circular such as elliptic shape, i.e., the cross section may be of any shape.

[0011] When a wire or a rod-like body is to be obtained for example, the drawing conditions of the present invention are that a temperature rising speed to the processing temperature is 1°C/sec to 100°C/sec, processing temperature is 50°C or higher and 200°C or lower (more preferably 150°C or lower), processing degree is 10% or more per one drawing processing (one pass), linear speed is 1 m/sec or more, and extruded material or rolled material is drawn. For example, when a pipe is to be obtained, the drawing temperature is 50°C or higher and 300°C or lower (more preferably 100°C or higher and 200°C or lower, and further preferably 100°C or higher and 150°C or lower), processing degree is 5% or higher per one drawing processing (preferably 10% or higher and more preferably 20% or higher), temperature rising speed to the drawing temperature is 1°C/sec to

100°C/sec, drawing speed is 1 m/sec or more, and extruded material or rolled material is drawn. If such a particular drawing processing is carried out, the crystal grain can be fine, and more particularly, the average crystal particle diameter can be reduced to 10μm or less. According to the present invention, by fine grain, the plastic workability can be enhanced even if the heating temperature is less than 250°C, and a desired wrought product can be obtained. After the drawing processing, the obtained drawn material may be heated to temperature of 100°C or higher and 300°C or lower, more preferably 150°C or higher and 300°C or lower. This heating annealing is effective for recovery of lattice defect introduced by the drawing processing, and for further finely dividing crystal grain by acceleration of recrystallization. It is preferable that keeping time of this heating temperature is about 5 to 20 minutes.

[0012] Examples of the plastic processing of the invention are forging processing, swaging processing, bending processing and the like. When the forging processing is to be carried out as the plastic processing, the following temperature conditions are suitable. That is, when reduction in height is r_1% and processing temperature is T°C, T satisfies the relation of $3r_1+150 > T \geq 3r_1+10$ (however, $20\% \leq r_1 < 80\%$, $T < 250°C$). For example, when reduction in height r_1 is equal to 20(%), the heating temperature T (°C) is lower than 250°C, especially 70°C or higher and lower than 210°C. When extruded material or rolled material which is not subjected to drawing processing is subjected to forging processing of reduction in height of 20%, crack or the like is generated and forging processing can not be carried out if the material is not heated to high temperature as high as 210°C or higher, but if the material is heated to such high temperature, the lifetime of a processing material such as a mold or roll is shortened. According to the present invention, the heating temperature when forging processing of reduction in height of 20% is carried out can be less than 210°C by the finely dividing effect of alloy structure using drawn material, and the lifetime of a processing material such as a mold or roll can be increased. When processing having reduction in height r_1 of more than 33% is to be carried out, the lower limit value of the heating temperature is set to a value obtained by the $3r_1+10$, and the upper limit value of the heating temperature is set to lower than 250°C while taking the lifetime of a mold or roll into consideration. Therefore, according to the present invention, when plastic processing having reduction in height of more than 40% which is industrially effective processing is to be carried out, even if the processing temperature is lower than 250°C, forging processing can sufficiently be carried out. In the severe processing in which reduction in height is 80% or higher, it is desired to heat the material to 250°C or higher.

[0013] When swaging processing is to be carried out as the plastic processing, the following temperature conditions are suitable. That is, when cross section reduction ratio is r_2% and processing temperature is T°C, T satisfies the relation of $3r_2+150 > T \geq 3r_2-30$ (however, $20\% \leq r_2 \leq 80\%$, $T < 250°C$). For example, when cross section reduction ratio r_2 is 20%, the heating temperature T (°C) can be less than 250°C, especially 30°C or higher and less than 210°C. Therefore, if the cross section reduction ratio is 20%, according to the present invention in which drawn material having fine alloy structure is used, lifetime of a processing material such as a mold can be increased in comparison with the conventional method in which extruded material or rolled material which is not subjected to drawing processing is used and heating to 210°C or higher is required. When cross section reduction ratio r_2 exceeds 33%, the lower limit value of the heating temperature is set to value obtained by the $3r_2-30$, and the upper limit value of the heating temperature is set to lower than 250°C while taking the lifetime of a mold or the like into consideration. In the present invention in which drawn material having fine alloy structure is used, when processing whose cross section reduction ratio exceeds 40% which is industrially effective processing is to be carried out, the swaging processing can be carried out at the processing temperature lower than 250°C. In the severe processing in which cross section reduction ratio exceeds 80%, it is desired to heat the material to 250°C or higher.

[0014] When the bending processing is to be carried out as the plastic processing, the following temperature conditions are suitable. That is, if thickness of a drawn material at the time of bending is t mm and bending radius is R mm and processing temperature is T°C, T satisfies (1) $250 > T \geq 250-250R/t$ when $0.1 \leq R/t \leq 1.0$, (2) $500-250R/t \geq T > 0$ when $1.0 < R/t \leq 1.9$, and (3) $25 \geq T > 0$ when $1.9 < R/t \leq 2.0$. For example, when a ratio R/t of bending radius R and thickness t of the drawn material is 1.0 to 1.9, the heating temperature T (°C) can be lower than 250°C, and especially the upper limit value can be 500-250R/t or lower. That is, as will be found from a later-described test result, the heating temperature can be lower than 100°C, further room temperature (e.g., 20°C). When R/t is 1.9 to 2.0, the heating temperature T (°C) can be 25°C or lower. In the conventional method in which extruded material or rolled material which is not subjected to drawing processing is used, if bending processing in which R/t is 1.0 to 2.0, especially about 1.5 to 1.0 is to be carried out, it is necessary to heat the material. On the other hand, according to the present invention, bending processing can sufficiently be carried out with R/t of 1.0 to 2.0 without heating the material due to the effect of fine crystal grain because drawn material is used, and heating equipment is unnecessary. Since heating operation is not necessary, lifetime of a processing material such as a mold can be increased. In the case of severe processing having R/t of less than 1.0, the lower limit value of the heating temperature is set to a value obtained by the 250-250R/t, and the upper limit value of the heating temperature is set to a value lower than 250°C while taking the lifetime of a mold or the like into consideration. According to the conventional method using extruded

material, it is necessary to heat the material to 200°C or higher in the severe processing having R/t of 1.2 or less, and especially in the case of severe processing having R/t of 1.0 or less, it is necessary to heat the material to 250°C or higher. Whereas, according to the present invention, since the drawn material in which crystal grain is fine is used, bending processing can sufficiently be carried out at the processing temperature of lower than 250°C even if the bending processing is severe processing in which R/t is 0.1 to 1.0.

[0015] The thickness of the drawn material is a diameter when the drawn material is a wire (line-like body) or a rod-like body and its cross sectional shape is circular, a thickness when the drawnmaterial is a wire or a rod-like body and its cross sectional shape is rectangular, and a difference between an outer diameter and an inner diameter when the drawn material is a pipe.

[0016] If R/t exceeds 2.0, the degree of the bending processing is low, and even extruded material or rolled material can be processed at roomtemperature and thus, it is not defined in the present invention. In the case of severe processing in which R/t is less than 0.1, since it is desired to heat the material to higher than 225°C, it is not defined in the present invention while taking the lifetime of a processing material such as a mold into consideration.

[0017] The present invention is effective in magnesium-based alloy having hcp structure having poor workability at around roomtemperature (e.g., 20°C) irrespective of alloy composition. For example, casting magnesium-based alloy or flatting magnesium-based alloy can be used. Concrete examples of the alloy are one having 0.1% by weight or more and 12% by weight or less Al and one having 0.1% by weight or more and 10% by weight or less Zn and 0.1% by weight or more and 2.0% by weight or less Zr. When the alloy contains Al, it may contain one or more of 0.1% by weight or more and 2.0% by weight or less Mn, 0.1% by weight or more and 5.0% by weight or less Zn, and 0.1% by weight or more and 5.0% by weight or less Si. As the alloy composition, it is possible to use AZ-based alloy, AS-based alloy, AM-based alloy, ZK-based alloy and the like in representative ASTM symbols. As contents of Al, 0.1 to less than 2.0% by weight Al and more than 2.0 to 12.0% by weight Al may be distinguished from each other. In addition to the above chemical compositions, it is general to use alloy including Mg and impurities. Examples of the impurities are Fe, Si, Cu, Ni, Ca and the like.

[0018] Examples of the AZ-based alloy having 2.0 to 12.0% by weight Al are AZ31, AZ61, AZ91 and the like. The AZ31 is a magnesium-based alloy, for example, containing Al: 2.5 to 3.5% by weight, Zn: 0.5 to 1.5% by weight, Mn: 0.15 to 0.5% by weight, Cu: 0.05% by weight or less, Si: 0.1% by weight or less, and Ca: 0.04% by weight or less. The AZ61 is a magnesium-based alloy, for example, containing Al: 5.5 to 7.2% by weight, Zn: 0.4 to 1.5% by weight, Mn: 0.15 to 0.35% by weight, Ni: 0.05% by weight or less, and Si: 0.1% by weight or less. The AZ91 is a magnesium-based alloy, for example, containing Al: 8.1 to 9.7% by weight, Zn: 0.35 to 1.0% by weight, Mn: 0.13% by weight or more, Cu: 0.1% by weight or less, Ni: 0.03% by weight or less, and Si: 0.5% by weight or less. The AZ-based alloy contains Al: 0.1 to less than 2.0% by weight, and examples of the AZ-based alloy are AZ10,AZ21 and the like. The AZ10 is a magnesium-based alloy, for example, containing Al: 1.0 to 1.5% by weight, Zn: 0.2 to 0.6% by weight, Mn: 0.2% by weight or more, Cu: 0.1% by weight or less, Si: 0.1% by weight or less, and Ca: 0.4% by weight or less. The AZ21 is a magnesium-based alloy, for example, containing Al: 1.4 to 2.6% by weight, Zn: 0.5 to 1.5% by weight, Mn: 0.15 to 0.35% by weight, Ni: 0.03% by weight or less, and Si: 0.1% by weight or less.

[0019] Examples of the AS-based alloy having Al of 2.0 to 12.0% by weight are AS41 and the like. The AS41 is a magnesium-based alloy, for example, containing Al: 3.7 to 4.8% by weight, Zn: 0.1% by weight or less, Cu: 0.15% by weight or less, Mn: 0.35 to 0.60% by weight, Ni: 0.001% by weight or less, and Si: 0.6 to 1.4% by weight. Examples of the AS-based alloy having Al of 0.1 to less than 2.0% by weight are AS21 and the like. The AS21 is a magnesium-based alloy, for example, containing Al: 1.4 to 2.6% by weight, Zn: 0.1% by weight or less, Cu: 0.15% by weight or less, Mn: 0.35 to 0.60% by weight, Ni: 0.001% by weight, and Si: 0.6 to 1.4% by weight.

[0020] Examples of the AM-based alloy are AM60, AM100 and the like. The AM60 is a magnesium-based alloy, for example, containing Al: 5.5 to 6.5% by weight, Zn: 0.22% by weight or less, Cu: 0.35% by weight or less, Mn: 0.13% by weight or more, Ni: 0.03% by weight or less, and Si: 0.5% by weight or less. The AM100 is a magnesium-based alloy, for example, containing Al: 9.3 to 10.7% by weight, Zn: 0.3% by weight or less, Cu: 0.1% by weight or less, Mn: 0.1 to 0.35% by weight, Ni: 0.01% by weight or less, and Si: 0.3% by weight or less.

[0021] Examples of the ZK-based alloy are ZK40, ZK60 and the like. The ZK40 is a magnesium-based alloy, for example, containing Zn: 3.5 to 4.5% by weight, and Zr: 0.45% by weight or more. The ZK60 is a magnesium-based alloy, for example, containing Zn: 4.8 to 6.2% by weight, and Zr: 0.45% by weight or more.

[0022] It is difficult to obtain sufficient strength with only magnesium, but if the above-described chemical compositions are containd, preferable strength can be obtained.

[0023] The present invention can be applied to produce a wrought product obtained by subjecting a drawn material to plastic processing, such as an eyeglass frame, a reinforcing frame of portable electronic equipment or others, a screw and the like.

Brief Description of the Drawings

[0024]

Figs. 1 (a) and 1 (b) are graphs showing whether forg-

ing processing can be carried out when forging processing is carried out while changing reduction in height at various temperatures, wherein Fig. 1(a) shows a drawn material and Fig. 1(b) shows extruded material;

Figs. 2(a) and 2(b) are graphs showing whether swaging processing can be carried out when swaging processing is carried out while changing cross section reduction ratio at various temperatures, wherein Fig. 2(a) shows a drawn material and Fig. 2(b) shows extruded material; and

Figs. 3(a) and 3(b) are graphs showing whether bending processing can be carried out when bending processing is carried out while changing a ratio R/t of bending radius R and thickness t of material to be processed at various temperatures, wherein Fig. 3 (a) shows a drawn material and Fig. 3(b) shows rolled material.

Best Mode for Carrying Out the Invention

[0025] Embodiments of the present invention will be explained below.

(Embodiment 1)

[0026] Extruded materials (ϕ4.0 mm, ϕ3.0 mm) of magnesium-based alloy (material corresponding to ASTM symbol AZ31) containing Al: 3.0% by weight, Zn: 1.0% by weight, Mn: 0.15% by weight, and balance comprising Mg and impurities were prepared. The extruded material of ϕ4.0 mm was subjected to drawing processing to ϕ3.0 mm at the temperature of about 160°C and processing degree of cross section reduction ratio per one pass of 20% or less (temperature rising speed to 160°C is about 10°C/sec, linear speed is 16 m/sec). After the drawing processing, thermal treatment of 350°C $\times$ 15 min was carried out. As a result, distortion caused at the time of drawing processing was eliminated and structure was equally divided finely by recrystallization.

[0027] The obtained drawn material of ϕ3.0 mm and the extruded material of ϕ3.0 mm which was not subj ected to drawing processing were cut into pieces of 3 mm length as test pieces. These test pieces were subjected to forging processing in a line axis direction with various reductions in height. At that time, the test pieces were heated to various temperatures in a range of 100°C to 250°C, and forging processing was carried out. Then, it was checked whether forging processing could be carried out. A result thereof is shown in Figs. 1(a) and 1(b). In Figs. 1(a) and 1(b), O shows that forging processing could be carried out, x shows that a crack or the like was generated and forging processing could not be carried out, and Δ shows that forging processing could be carried out but heating temperature was high and there was a problem in terms of lifetime of a mold. In Figs. 1(a) and 1(b), an equation (1) is $T = 3r_1+150$ and an equation (2) is $T = 3r_1+10$. In the equations (1) and (2), T represents heating temperature, and r_1 represents reduction in height.

[0028] As shown in Fig. 1(a), when drawn material is to be subjected to forging processing, if the drawn material is heated to the temperature T°C which satisfies $T \geq 3r_1+10$ with respect to reduction in height of r_1 (%), forging processing could be carried out. That is, when drawn material is used, it can be found that even if it is heated to temperature lower than 250°C, forging processing can sufficiently be carried out. Especially forging processing having reduction in height of about 20 to 30%, forging processing could be carried out sufficiently even at temperature that satisfied $T < 3r_1+150$. When the drawn material was heated to 250°C, forging processing could be carried out with reduction in height in a range of 20 to 80%, but if lifetime of a mold is taken into consideration, it is preferable that the drawn material is heated to lower than 250°C.

[0029] On the other hand, when extruded material which was not subjected to drawing processing was subjected to forging processing as shown in Fig. 1(b), the extruded material could not be processed without heating the extruded material to temperature that satisfied $T \geq 3r_1+150$ with respect to reduction in height of r_1 (%). Especially in the case of forging processing with reduction in height of more than 40% which is industrially effective processing, it can be found that the material must be heated to 250°C or higher.

[0030] Similar tests were carried out using magnesium-based alloys having different compositions. That is, after extruded material was subjected to drawing processing, drawn material subjected to thermal treatment was subjected to forging processing in the linear axis direction at various temperatures in a range of 100 to 250°C with various reductions in height. Compositions of magnesium-based alloys subjected to the test will be shown below.

A magnesium-based alloy containing Al: 1.2% by weight, Zn: 0.4% by weight, Mn: 0.3% by weight, and balance comprising Mg and impurities (material corresponding to ASTM symbol AZ10)

A magnesium-based alloy containing Al: 6.4% by weight, Zn: 1.0% by weight, Mn: 0.28% by weight, and balance comprising Mg and impurities (material corresponding to ASTM symbol AZ61)

A magnesium-based alloy containing Al: 9.0% by weight, Zn: 0.7% by weight, Mn: 0.1% by weight, and balance comprising Mg and impurities (material corresponding to ASTM symbol AZ91)

A magnesium-based alloy containing Al: 1.9% by weight, Mn: 0.45% by weight, Si: 1.0% by weight, and balance comprising Mg and impurities (material corresponding to ASTM symbol AS21)

A magnesium-based alloy containing Al: 4.2% by weight, Mn: 0.50% by weight, Si: 1.1% by weight, and balance comprising Mg and impurities (material corresponding to ASTM symbol AS41)

A magnesium-based alloy containing Al: 6.1% by weight, Mn: 0.44% by weight, and balance comprising Mg and impurities (material corresponding to ASTM symbol AM60)

A magnesium-based alloy containing Zn: 5.5% by weight, Zr: 0.45% by weight, and balance comprising Mg and impurities (material corresponding to ASTM symbol ZK60)

[0031] With any of the above samples, if it was heated to temperature T°C that satisfied $T \geq 3r_1+10$ with respect to reduction in height of r_1 (%), forging processing could be carried out and even if it was heated to lower than 250°C, it could be processed sufficiently.

(Embodiment 2)

[0032] The drawn material (material corresponding to ASTM symbol AZ31) of ϕ3.0 mm prepared under the same drawing conditions as those of the embodiment 1, and the extruded material (material corresponding to ASTM symbol AZ31) of ϕ3.0 mm which was not subjected to drawing processing were subjected to swaging processing. The swaging processing was carried out in such a manner that test pieces were heated to various temperatures in a range of 100°C to 250°C, and cross section reduction ratio was changed so that the following seven kinds of diameters could be obtained: i.e., ϕ2.7 mm (cross section reduction ratio 19%), ϕ2.4 mm (cross section reduction ratio 36%), ϕ2.3 mm (cross section reduction ratio 41.2%), ϕ2.1 mm (cross section reduction ratio 51%), ϕ1.9 mm (cross section reduction ratio 59.9%), ϕ1.6 mm (cross section reduction ratio 71.6%) and ϕ1.4 mm (cross section reduction ratio 78.2%). Then, it was checked whether swaging processing could be carried out. A result thereof is shown in Figs. 2(a) and 2 (b). In Figs. 2(a) and 2(b), O shows that swaging processing could be carried out, × shows that a crack or the like was generated and swaging processing could not be carried out, and Δ shows that swaging processing could be carried out but heating temperature was high and there was a problem in terms of lifetime of a mold. In Figs. 2 (a) and 2(b), an equation (3) is $T = 3r_2+150$ and an equation (4) is $T = 3r_2-30$. In the equations (3) and (4), T represents heating temperature, and r_2 represents cross section reduction ratio.

[0033] As shown in Fig. 2(a), when drawn material is to be subj ected to swaging processing, if the drawn material is heated to the temperature T°C which satisfies $T \geq 3r_2-30$ with respect to cross section reduction ratio r_2 (%), swaging processing could be carried out. That is, when drawn material is used, it can be found that even if it is heated to temperature lower than 250°C, swaging processing can sufficiently be carried out. Especially swaging processing having cross section reduction ratio of about 20 to 30%, swaging processing could be carried out sufficiently even at temperature T°C that satisfied $T < 3r_2+150$. When the drawn material was heated to 250°C, swaging processing could be carried out with cross section reduction ratio in a range of 20 to 80%, but if lifetime of a mold is taken into consideration, it is preferable that the drawn material is heated to lower than 250°C.

[0034] On the other hand, when extruded material which was not subjected to drawing processing was subjected to swaging processing as shown in Fig. 2(b), the extruded material could not be processed without heating the extruded material to temperature T°C that satisfied $T \geq 3r_2+150$ even if the cross section reduction ratio r_2 is about 20 to 30%. Especially when the cross section reduction ratio is 40% or more, the swaging processing could not be carried out without heating the material to 250°C or higher.

[0035] Similar tests were carried out using magnesium-based alloys having different compositions. That is, after extruded material was subjected to the same drawing processing as that of the embodiment 1, drawn material subjected to thermal treatment was subj ected to swaging processing with various cross section reduction ratio and at various temperatures in a range of 100 to 250°C so that the above seven kinds of diameters could be obtained. As the magnesium-based alloys, the following materials having the same compositions as those shown above were used, i.e., a material corresponding to AZ10, a material corresponding to AZ61, a material corresponding to AZ91, a material corresponding to AS21, a material corresponding to AS41, a material corresponding to AM60 and a material corresponding to ZK60.

[0036] As a result of the test, with any of the samples, swaging processing could be carried out by heating the drawing material to the temperature T°C that satisfied $T \geq 3r_2-30$ with respect to cross section reduction ratio r_2 (%), and the drawing material could sufficiently be processed even if the heating temperature is lower than 250°C.

(Embodiment 3)

[0037] A drawn material of ϕ3.0 mm (material corresponding to ASTM symbol AZ31) prepared under the same drawing conditions as those of the embodiment 1 was further subjected to drawing processing (temperature 160°C, cross section reduction ratio per one pass was about 15 to 18%, temperature rising speed to 160°C was about 10°C/sec, linear speed was 20 m/sec), and a linear material having rectangular cross sectional shape (thickness t 1 mm × width 3 mm) was obtained. This linear material was subjected to thermal treatment of 350°C × 15 min, and test pieces were obtained. Further, a rolled material having the same component (material corresponding to ASTM symbol AZ31) as that used in the embodiment 1 and thickness t of 1 mm was prepared, it was cut into width of 3 mm as test pieces.

[0038] The test pieces of drawn material of thickness t 1 mm × width 3 mm, and rolled material of thickness t

1 mm × width 3 mm were subjected to bending processing with various bending radii R. The bending processing was carried out by heating the test pieces at various temperature in a range of 20 to 250°C. Then, it was checked whether bending processing could be carried out. Figs. 3 (a) and 3 (b) show a result thereof. In Figs. 3(a) and 3 (b), O shows that bending processing could be carried out, × shows that a crack or the like was generated and bending processing could not be carried out, and Δ shows that bending processing could be carried out but heating temperature was high and there was a problem in terms of lifetime of a mold. In Figs. 3(a) and 3(b), an equation (5) is $T = -250R/t+250$ and an equation (6) is $T=-250R/t+500$. In the equations (5) and (6), T represents heating temperature, R represents a bending radius and t represents a thickness of test piece.

[0039] As shown in Fig. 3(a), when drawn material is to be subj ected to bending processing, if a ratio R/t of the bending radius R (mm) and thickness t (mm) of the test piece satisfied $0.1 \leq R/t \leq 1.0$, the bending processing could be carried out by heating the test piece to temperature T°C that satisfied $T \geq -250R/t+250$. Especially when the R/t was more than 1.0 and less than 2.0, the bending processing could sufficiently be carried out even if the temperature satisfied $T < -250R/t+500$, specifically, the temperature was 20°C that is around the room temperature. Further, the bending processing could sufficiently be carried out at 20°C even if the R/t was 2.0. That is, when drawn material is used, it can be found that the bending processing can sufficiently be carried out even if the heating temperature is lower than 250°C. When the drawn material was heated to 250°C, bending processing could be carried out with the R/t in a range of 1.0 to 2.0, but if lifetime of a mold is taken into consideration, it is preferable that the drawn material is heated to lower than 250°C.

[0040] On the other hand, when rolled material which was not subjected to drawing processing was subjected to bending processing as shown in Fig. 3(b), the rolled material could not be processed without heating the rolled material to temperature T°C that satisfied $T \geq -250R/t+500$ even if the R/t was 1.0 or more. In the case of severe processing in which the R/t was 0.5 or less, bending processing could not be carried out even if the rolled material was heated to 250°C.

[0041] Similar tests were carried out using magnesium-based alloys having different compositions. That is, after extruded material was subjected to the same drawing processing as that of the embodiment 1, drawn material was subjected to drawing processing to obtain rectangular cross section and then, was subjected to thermal treatment. This drawn material was subjected to bending processing with various bending radii so that the R/t falls in a range of 0.1 to 2.0 and at various temperatures in a range of 20 to 250°C. As the magnesium-based alloys, the following materials having the same compositions as those shown above were used, i.e., a material corresponding to AZ10, a material corresponding to AZ61, a material corresponding to AZ91, a material corresponding to AS21, a material corresponding to AS41, a material corresponding to AM60 and a material corresponding to ZK60.

[0042] As a result of the test, any of samples could be sufficiently subjected to bending processing by heating the samples to the temperature T°C satisfying $T \geq -250R/t+250$ when $0.1 \leq Rt \leq 1.0$. In addition, any of samples could be sufficiently subjected to bending processing even in the case where the temperature T°C is smaller than $-250R/t+500$ when $1.0 < R/t \leq 1.9$ or in the case where the temperature T°C is 20°C which is around room temperature when R/t is 1.0 or more. As described above, any of the samples could be sufficiently subjected to bending processing even if heating was carried out at less than 250°C.

Industrial Applicability

[0043] As explained above, according to the producing method of magnesium-based alloy wrought product of the present invention, there is an excellent effect that plastic processing can be carried out at processing temperature of lower than 250°C by using a drawn material obtained by drawing processing. Therefore, according to the invention, it is unnecessary to increase a temperature as high as 250°C or more at the time of plastic processing, unlike the conventional technique in which extruded material or rolled material is subjected to plastic processing as it is. Therefore, it is possible to increase lifetime of material to be processed such as a mold and a roll, and to obtain a wrought product of magnesium-based alloy with excellent productivity.

Claims

1. A producing method of a magnesium-based alloy wrought product, wherein a drawn material made of magnesium-based alloy obtained by drawing processing is subjected to plastic processing into a wrought product at processing temperature of lower than 250°C.

2. A producing method of a magnesium-based alloy wrought product, wherein a drawn material made of magnesium-based alloy obtained by drawing processing is subjected to forging processing into a wrought product at processing temperature T°C that satisfies the following conditions:

    when reduction in height is r_1% and processing temperature is T°C,
    T is in a range of $3r_1+150 > T \geq 3r_1+10$, however $20\% \leq r_1 < 80\%$ and $T < 250°C$.

3. A producing method of a magnesium-based alloy wrought product wherein a drawn material made of

magnesium-based alloy obtained by drawing processing is subjected to swaging processing into a wrought product at processing temperature T°C that satisfies the following conditions:

when cross section reduction ratio is r_2% and processing temperature is T°C,
T is in a range of $3r_2+150 > T \geq 3r_2-30$, however $20\% \leq r_2 \leq 80\%$ and $T < 250°C$.

4. A producing method of a magnesium-based alloy wrought product wherein a drawn material made of magnesium-based alloy obtained by drawing processing is subj ected to bending processing into a wrought product at processing temperature T°C that satisfies the following conditions:

when the thickness of the drawn material when it is to be bent is t mm and bending radius is R mm and processing temperature is T°C,
T is in a range of
$250 > T \geq 250-250R/t$ when $0.1 \leq R/t \leq 1.0$,
$500-250R/t \geq T > 0$ when $1.0 < R/t \leq 1.9$, and
$25 \geq T > 0$ when $1.9 < R/t \leq 2.0$.

5. The producing method of a magnesium-based alloy wrought product according to any one of claims 1 to 4, wherein the magnesium-based alloy contains 0.1 to 12% by weight Al.

6. The producing method of a magnesium-based alloy wrought product according to claim 5, wherein the magnesium-based alloy contains at least one of 0.1 to 2.0% by weight Mn, 0.1 to 5.0% by weight Zn and 0.1 to 5.0% by weight Si.

7. The producing method of a magnesium-based alloy wrought product according to any one of claims 1 to 4, wherein the magnesium-based alloy contains 0.1 to 10% by weight Zn and 0.1 to 2.0% by weight Zr.

Fig. 1 (a)

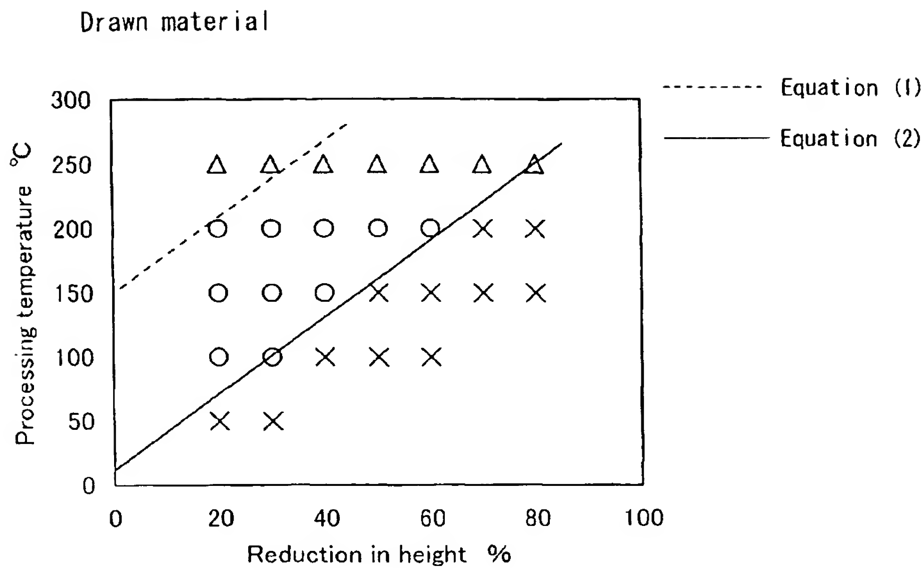

Drawn material
Equation (1)
Equation (2)
Processing temperature °C
300
250
200
150
100
50
0
0
20
40
60
80
100
Reduction in height %

Fig. 1 (b)

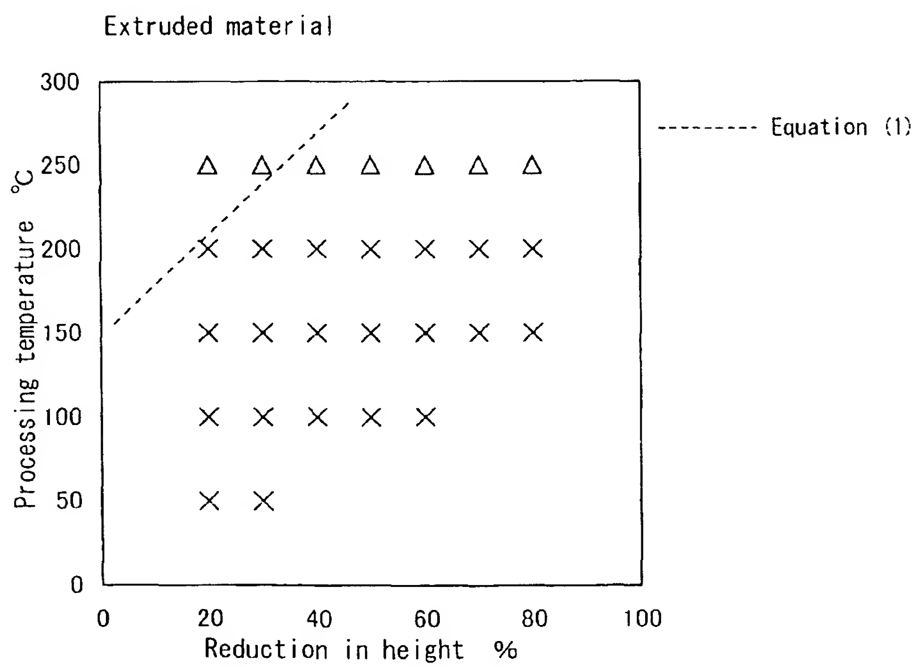

Extruded material
Equation (1)
Processing temperature °C
300
250
200
150
100
50
0
0
20
40
60
80
100
Reduction in height %

Fig. 2 (a)

Drawn material

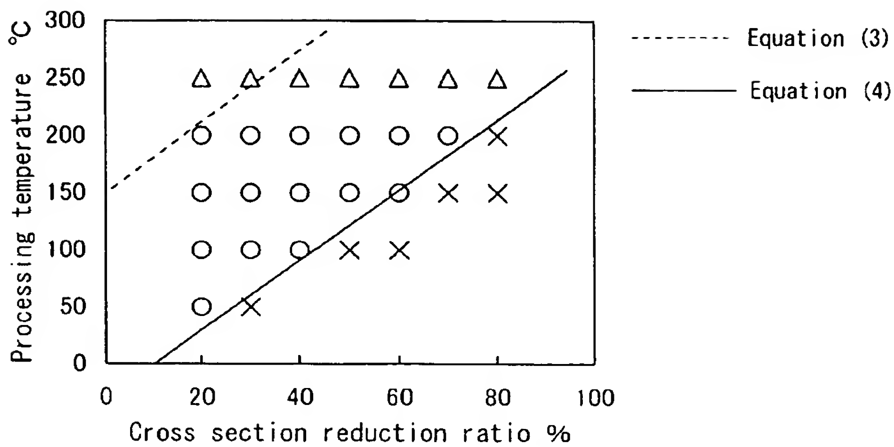


Fig. 2 (b)

Extruded material

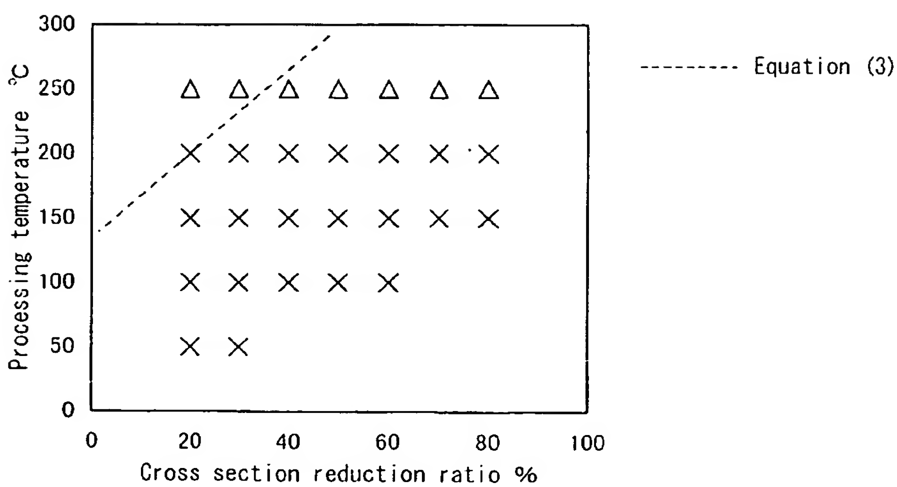


Fig. 3 (a)

Drawn material

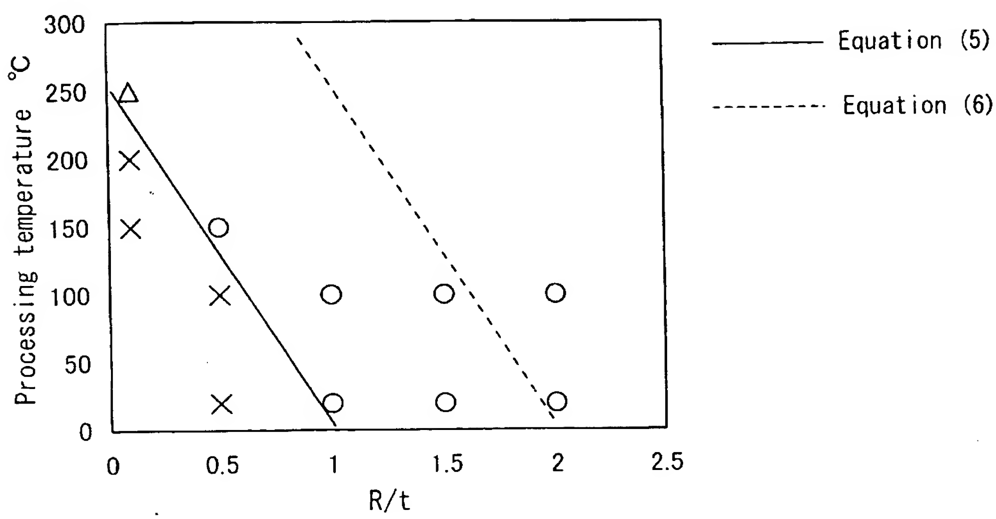
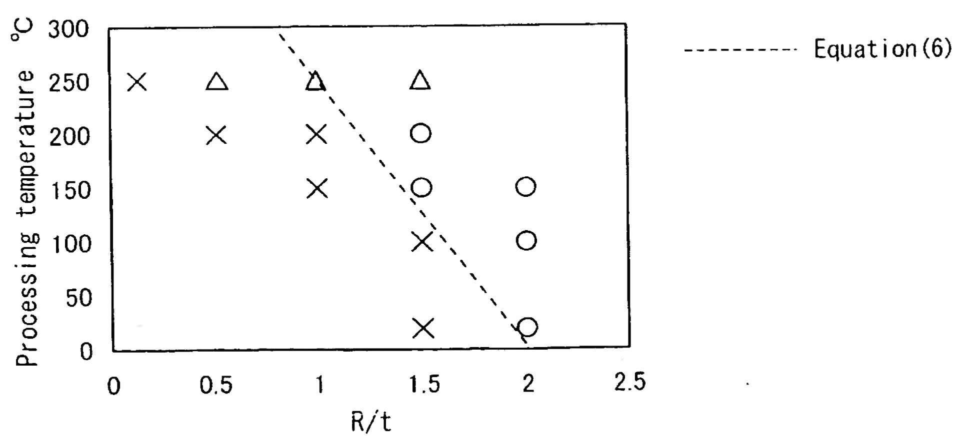


Fig. 3 (b)

Extruded material



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2004/005226

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl[7] C22F1/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl[7] C22C23/00-23/06, 45/00-45/10, C22F1/06, B21C1/00-19/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Toroku Jitsuyo Shinan Koho	1994-2004
Kokai Jitsuyo Shinan Koho	1971-2004	Jitsuyo Shinan Toroku Koho	1996-2004

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
JICST

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2002-371334 A (Daido Steel Co., Ltd.), 26 December, 2002 (26.12.02), Claims; column 1, lines 22 to 30; column 2, lines 47 to 50; column 3, lines 26 to 32; column 6, lines 30 to 35 (Family: none)	1-7
X	OISHI et al., "Kokyodo Magnesium Gokin Wire no Kaihatsu", SEI Technical Review, 2003 February, No.162, pages 57 to 61	1-7
P,X	JP 2003-293069 A (Sumitomo Denko Steel Wire Kabushiki Kaisha), 15 October, 2003 (15.10.03), Claims; column 37, line 38 to column 38, line 30 & WO 2002/99148 A1	1-7

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search 14 July, 2004 (14.07.04)	Date of mailing of the international search report 27 July, 2004 (27.07.04)
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer
Facsimile No.	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2004/005226

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	JP 2004-17114 A (Daido Steel Co., Ltd.), 22 January, 2004 (22.01.04), Claims; page 4, lines 18 to 20 (Family: none)	1-7
A	JP 2001-071037 A (Matsushita Electric Industrial Co., Ltd.), 21 March, 2001 (21.03.01), Column 5, line 2 to column 6, line 26 (Family: none)	4
A	JP 60-149751 A (ITT Industries Inc.), 07 August, 1985 (07.08.85), Page 3, upper left column, line 8 to upper right column, line 14; page 7, upper left column, lines 4 to 11 & BR 8404599 A & AU 8433100 A & EP 139168 A Page 4, line 30 to page 6, line 1; page 16, line 25 to page 17, line 6	2,3

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2004/005226

<on the Subject of the Search>

Claims 1 to 7 involve all types of "drawing". But, only "the specific drawing" described in page 2, line 7 in the specification, that is, the specific "drawing" described in page 2, line 26 to page 3, line 14 in the specification is disclosed in the meaning of PCT Article, and therefore, claims 1 to 7 lack the support in the meaning of PCT Article 6.

Accordingly, the search has been carried out with respect to the range supported by and disclosed in the specification, that is, the specific "drawing" described in page 2, line 26 to page 3, line 14 in the specification.

Form PCT/ISA/210 (extra sheet) (January 2004)